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Environmental Protection
Agency

Great Lakes
National Program Office
77 West Jackson Boulevard
Chicago, Illinois 60604

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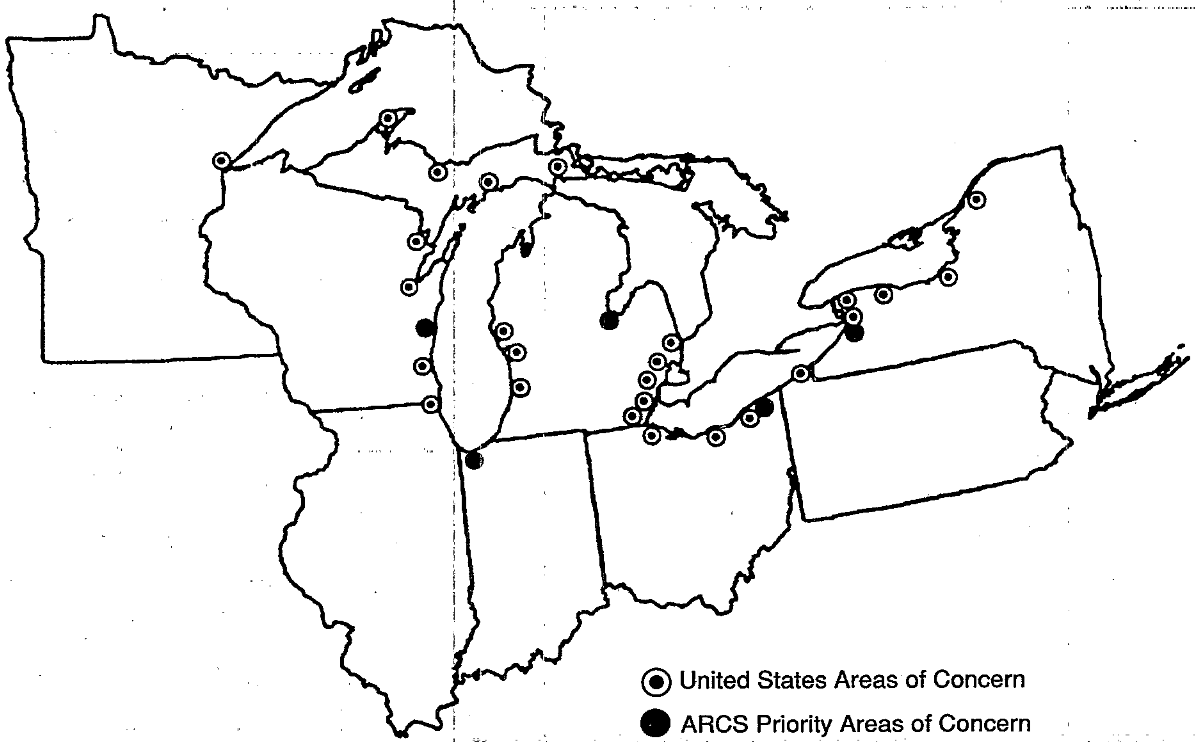
August 1994

EPA

Assessment and Remediation Of Contaminated Sediments (ARCS) Program

FINAL SUMMARY REPORT



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Assessment and Remediation of Contaminated Sediments (ARCS) Program

Final Summary Report

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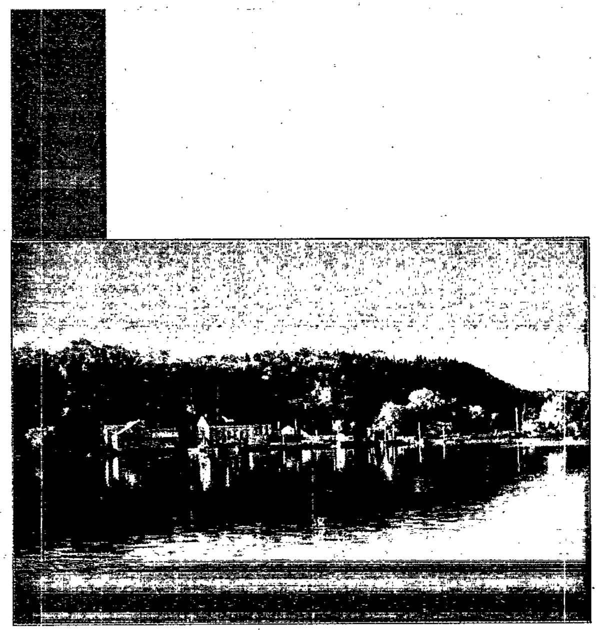
Final Summary Report

In support of the United States commitment to the Great Lakes Water Quality Agreement with Canada, § 118(c)(3) of the Clean Water Act, added by the Water Quality Act of 1987, authorized the U.S. Environmental Protection Agency (USEPA), through the Great Lakes National Program Office (GLNPO), to "... carry out a five-year study and demonstration projects relating to the control and removal of toxic pollutants in the Great Lakes, with emphasis on the removal of toxic pollutants from bottom sediments."

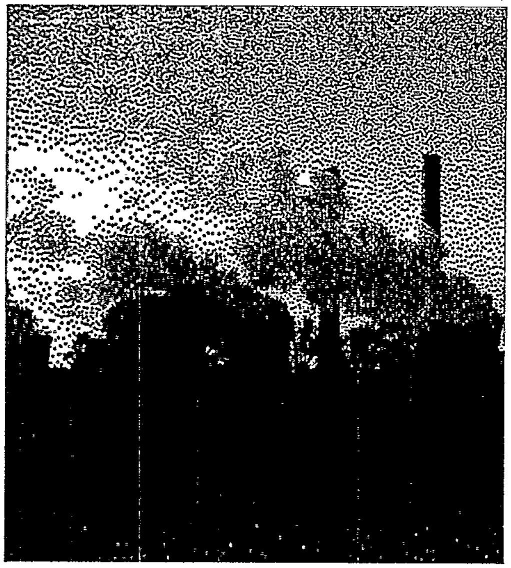
This report sets forth the major findings of the Assessment and Remediation of Contaminated Sediments (ARCS) Program.

Introduction



The Great Lakes are an extraordinary natural resource. These five lakes hold 95 percent of the surface freshwater found in the United States and represent 18 percent of the world's supply of surface freshwater. This wealth of freshwater reaches deep into North America, sustaining abundant and diverse populations of plants and animals.

The Great Lakes have long been a source of economic strength. They serve as a leading outlet for shipments of farm products from the Great Plains and Midwest. Because of the presence of large quantities of iron ore, limestone, and coal, and a readily available waterway system for transport of these resources, the Great Lakes region has become an industrial heartland for both the United States and Canada. About 60 percent of the cars made in America today are built in five of the Great Lakes states. Many other productive industries are also important, including the forest product, metals, mining, and chemical industries. The Great Lakes provide drinking water for millions of people, provide water for industrial processes, and sustain many recreational activities, including a multibillion-dollar sport fishing industry.



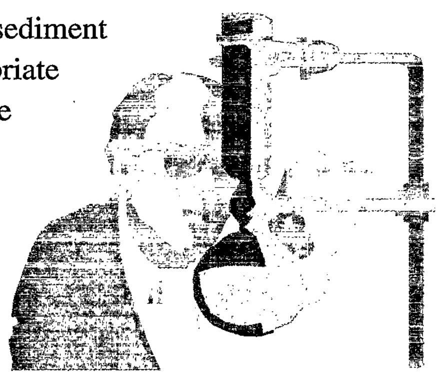
Years of point and nonpoint source discharges from industrial and municipal facilities and urban and agricultural runoff to the Great Lakes and its tributaries have introduced toxic substances to, and thereby significantly contributed to the contamination of, the Great Lakes ecosystem. In many cases, contaminants that are introduced directly into the tributaries travel downstream, thereby contributing to the contamination of the Great Lakes proper. Because of the vast size and volume of the Great Lakes, the flushing process is slow, taking years for the water in the lakes to be replenished. This slow flushing allows contaminants in the water column to settle out and accumulate in bottom sediments, such that the sediments become a repository for contaminants. Once the contaminated sediments move out of the harbors and tributaries into the lakes themselves, the contamination may persist for a long time and, if widespread, may be virtually impossible to remediate.

Although discharges of toxic substances to the Great Lakes have been reduced in the last 20 years, persistent high concentrations of contaminants in the bottom sediments of rivers and harbors have raised considerable concern about potential risks to aquatic organisms, wildlife, and humans. Exposure to contaminated sediments may impact aquatic life through the development of cancerous tumors, loss of suitable habitat, and toxicity to fish and benthic organisms. Exposure can also impact wildlife and human health via the bioaccumulation of toxic substances through the food chain. As a result, advisories against fish consumption are in place in many locations around the Great Lakes. These advisories, along with closed commercial fisheries and restrictions on navigational dredging, have a significant adverse economic impact in the areas affected.

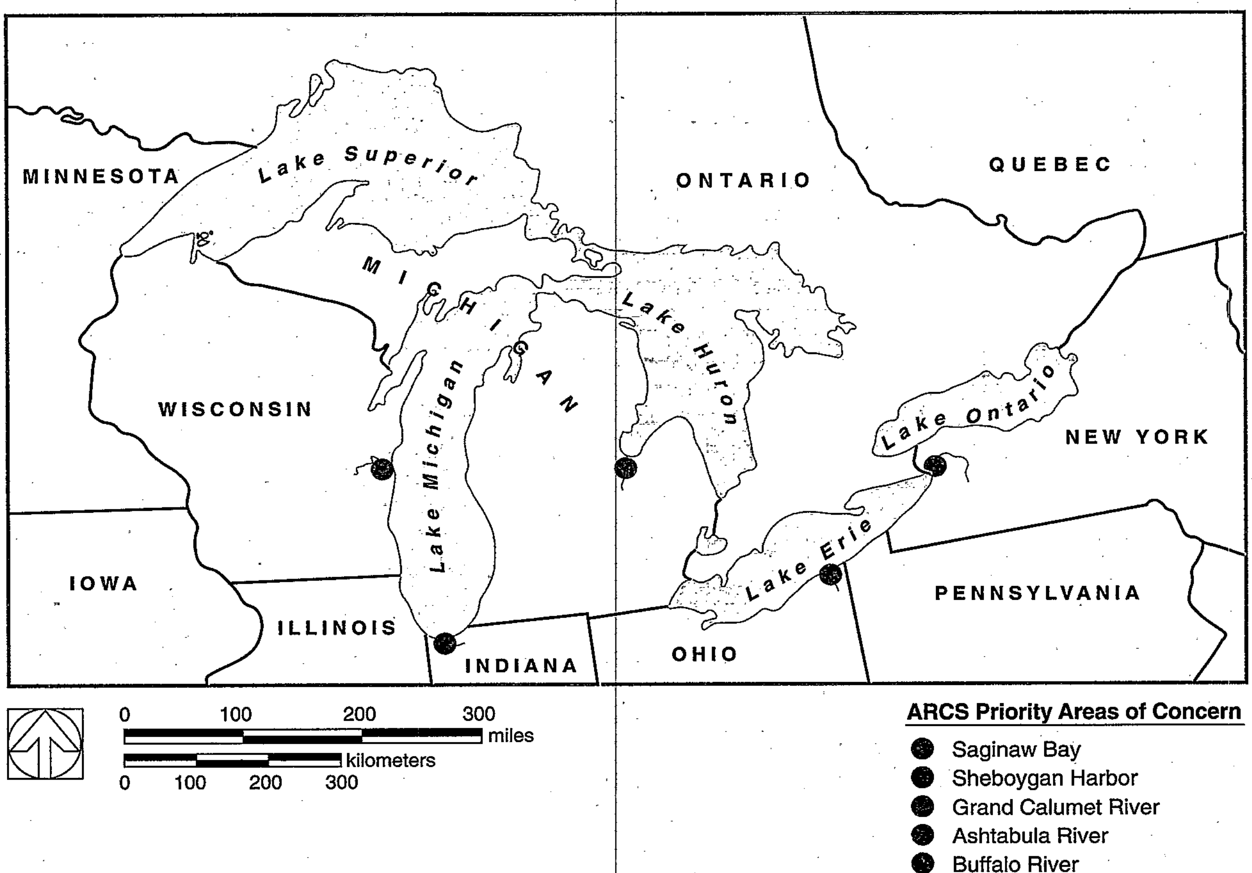
There is growing scientific awareness of the significance of bottom sediments to continuing contamination of the Great Lakes food web. In 1992, the U.S. Environmental Protection Agency (USEPA), the State of Wisconsin, and many cooperating agencies and universities completed a major study of the sources, pathways, and fates of polychlorinated biphenyls (PCBs) in Green Bay, an arm of Lake Michigan where concentrations of these contaminants have been especially elevated. One finding of the study was that more than 90 percent of the ongoing PCB contamination in Green Bay sport fish came from contaminated bottom sediments, both within the bay and in the Fox River. Monitoring of Lake Superior during the past decade suggests a similar conclusion—that the release of PCBs from bottom sediments is the dominating source of food web contamination.

In 1987, a protocol (Annex 14) that was added to the already existing Great Lakes Water Quality Agreement between the United States and Canada (originally signed in 1972) specifically recognized that there is a need to jointly address concerns about persistent toxic contaminants in the Great Lakes. The identified objective of Annex 14 of the Agreement is for the signing parties, in cooperation with state and provincial governments, to "... identify the nature and extent of sediment pollution of the Great Lakes System." These findings are to then be used to ". . . develop methods to evaluate both the impact of polluted sediment on the Great Lakes System, and the technological capabilities of programs to remedy such pollution." The information obtained through these activities is to be used to guide development of Lakewide Management Plans and Remedial Action Plans (RAPs) for specific Areas of Concern (AOCs) in the Great Lakes Basin. The AOCs (43 in all) were previously documented by the Great Lakes Water Quality Board of the International Joint Commission (IJC; Annex 2 of the Great Lakes Water Quality Agreement), and are defined as places where beneficial uses of water resources such as drinking, swimming, fishing, and navigation are impaired by anthropogenic pollution or perturbation. The IJC has documented that sediment contamination is a major cause of such impairment in 42 of the 43 AOCs. Contaminated sediments have been determined to be a problem in all of the 26 United States and the 5 joint United States/Canadian AOCs.

Concerns about Great Lakes sediment contamination have prompted numerous studies and projects, both individually and in cooperation with one another, by United States and Canadian Federal, State, and local government agencies, universities, and other private organizations. These projects have focused on such issues as how to determine the location and severity of sediment contamination and how to select appropriate sediment remedial actions. Some of these activities have included consideration of rivers and other tributaries to the Great Lakes as sources of contaminated sediments to the lakes.



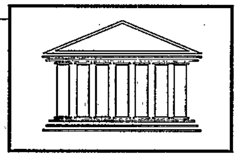
In support of the United States commitment to the Great Lakes Water Quality Agreement, § 118(c)(3) of the Clean Water Act, added by the Water Quality Act of 1987, authorized the USEPA, through the Great Lakes National Program Office (GLNPO), to "... carry out a five-year study and demonstration projects relating to the control and removal of toxic pollutants in the Great Lakes, with emphasis on the removal of toxic pollutants from bottom sediments." The Water Quality Act of 1987 also specified five AOCs as requiring priority consideration in conducting the demonstration projects. These AOCs are Saginaw Bay, Michigan; Sheboygan Harbor, Wisconsin; Grand Calumet River, Indiana; Ashtabula River, Ohio; and Buffalo River, New York.



The ARCS Program Overview

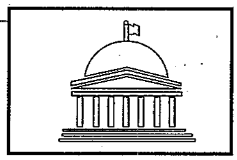
ARCS Program Participating Organizations

FEDERAL



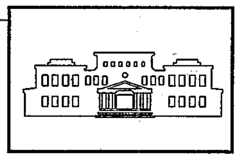
U.S. Environmental Protection Agency
U.S. Army Corps of Engineers
U.S. Bureau of Mines
U.S. Department of Energy
U.S. Fish and Wildlife Service
U.S. Geological Survey
National Oceanic & Atmospheric Administration

STATE/LOCAL



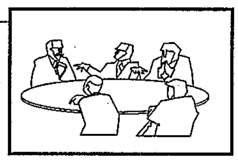
Erie County Department of Environment and Planning
Illinois Natural History Survey
Indiana Department of Environmental Management
Michigan Department of Natural Resources
New York State Department of Environmental Conservation
Ohio Environmental Protection Agency
Wisconsin Department of Natural Resources

ACADEMIC



The Citadel
DePaul University
Memphis State University
Michigan State University
Saginaw Valley State University
State University College at Buffalo
State University of New York at Buffalo
University of California at Santa Barbara
University of Michigan
University of Minnesota
University of Wisconsin at Milwaukee
Wright State University

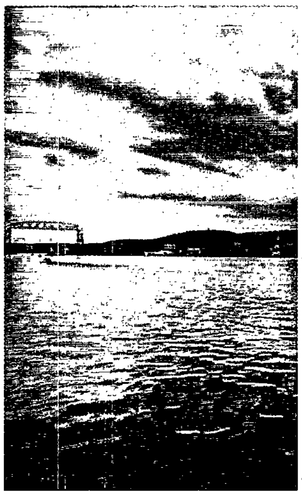
ADDITIONAL



Ashtabula Remedial Action Plan Citizens Committee
Atlantic States Legal Foundation
Battelle Marine Science Laboratory
Buffalo Remedial Action Plan Citizens Committee
Canada Centre for Inland Waters
Environment Canada
Grand Calumet Task Force
Great Lakes United
Lake Michigan Federation
Michigan United Conservation Clubs
National Water Research Institute (Canada)
National Wildlife Federation
Saginaw Bay Alliance
Sheboygan Remedial Action Plan Citizens Committee
Sierra Club
Smithsonian Institution
Wastewater Technology Centre (Canada)

To fulfill the requirements of § 118(c)(3) of the Clean Water Act, GLNPO initiated the ARCS Program. At the outset, USEPA recognized that active participation by numerous and diverse interests would be required to successfully complete activities initiated under the ARCS Program. Accordingly, participation was readily sought from other Federal and State agencies, universities, and public interest groups. This ensured that national expertise about sediment assessment and remediation techniques was identified and available for use during ARCS Program activities, and that concerns regarding sediment contamination issues in general were adequately addressed. Thus, while GLNPO administered the ARCS Program and coordinated program activities, this was truly a multi-organizational endeavor.

ARCS Program Objectives and Issues Addressed



A primary goal of the ARCS Program was to develop an integrated, comprehensive approach to assessing the extent and severity of sediment contamination, assessing the risks associated with that contamination, and selecting appropriate remedial responses. This information was developed to help support implementation of RAPs at the Great Lakes AOCs. The ARCS Program developed the following objectives that were designed to meet this goal and the requirements of § 118(c)(3) of the Clean Water Act:

- Assess the nature and extent of bottom sediment contamination at selected Great Lakes AOCs;
- Demonstrate and evaluate the effectiveness of selected remedial options, including removal, immobilization, and advanced treatment technologies, as well as the "no action" alternative; and
- Provide guidance on contaminated sediment problems and remedial alternatives in the AOCs and other locations in the Great Lakes.

Consistent with these objectives, the ARCS Program directed its efforts toward developing and demonstrating sediment assessment and cleanup approaches that are scientifically sound, and technologically and economically feasible. The ARCS Program was intended to provide environmental managers at AOCs and elsewhere with the tools and information necessary for making informed, cost-effective, and environmentally sound decisions in addressing a local contaminated sediment problem. Although ARCS was not a cleanup program, the activities undertaken generated valuable information that can now be applied in making cleanup decisions at the five priority AOCs and elsewhere.

To meet the above objectives, the ARCS Program identified the following important and complex issues that needed to be addressed:

- Determining whether, and if so to what extent, sediments are contaminated with substances that are harmful and/or bioavailable to benthos, fish, wildlife, and/or humans;
- Defining the three-dimensional boundaries of a sediment contamination problem;
- Identifying available remedial alternatives, what their limitations are, and how effective they are likely to be;
- Determining the environmental impacts that might result from a remedial action; and
- Determining the economic costs associated with implementing remedial actions.

Major Findings and Recommendations of the ARCS Program

The major findings and recommendations of the ARCS Program include the following:

- Use of an *integrated sediment assessment approach*, incorporating chemical analyses, toxicity testing, and benthic community surveys, is essential to define the magnitude and extent of sediment contamination at a site.

- Semiquantitative screening-level analyses allow a greater number of sites to be sampled than traditional approaches and thus are cost-effective tools for focusing resources on areas that need detailed assessment.

- It is usually necessary to collect and analyze both surface and deep-core sediment samples to accurately delineate the boundaries of a sediment contamination problem.

- The ARCS Program identified a short list of toxicity and bioaccumulation tests from which a subset should be selected and conducted on a site-specific basis to adequately characterize the toxicity of contaminants associated with sediments.

■ *Risk assessment and modeling activities* are valuable techniques for evaluating the potential impacts associated with contaminated sediments.

- Reductions in risk created by the implementation of a remedial action can only be evaluated if baseline risks are adequately established.

- Mass balance modeling is a useful tool for predicting the changes in risk resulting from the implementation of various remedial actions, including the "no action" alternative.

- A complex series of mass balance models can produce meaningful results with reasonable data requirements.

■ A number of *treatment technologies* are effective in removing or destroying sediment contaminants.

- Demonstrations of treatment technologies in the laboratory and the field documented that individual treatment technologies are only effective on specific types of sediment contaminants, with no one treatment technology able to adequately treat all contaminants.

- The use of sediment treatment technologies may be appropriate in some applications; however, they will remain more costly (by approximately an order of magnitude) than traditional disposal methods without further process development and refinement.

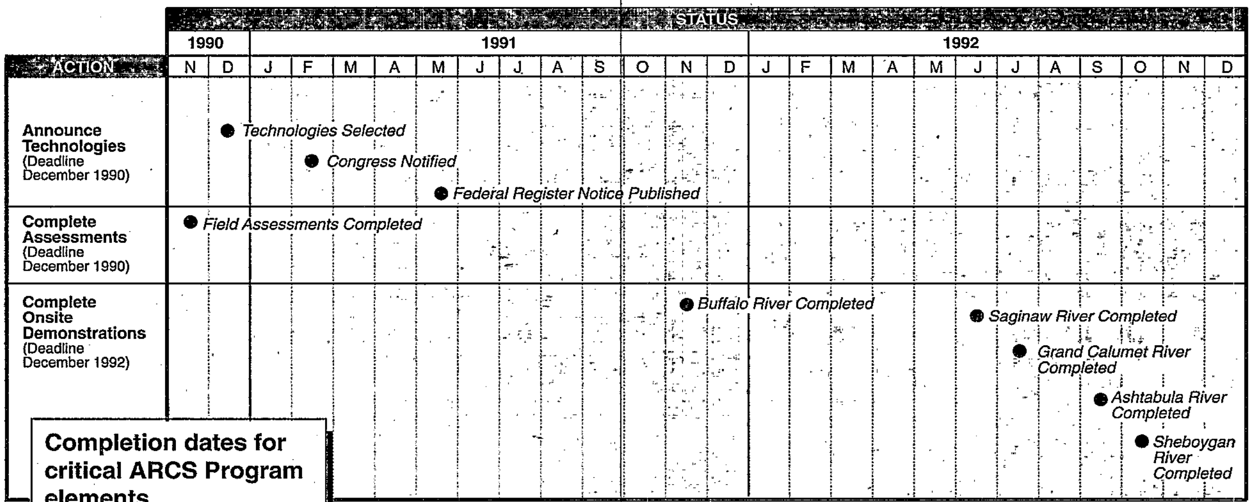
- Sediment washing technologies were found to be promising in that they were both feasible and could be conducted at a relatively lower cost, although they are applicable for only certain types of sediment.

■ Broad *public involvement and education* are critical in any sediment assessment and remedy selection study in order to develop a common understanding of the problem and the environmental and economic impacts of alternative remedial actions.

Each of these major conclusions is discussed in further detail in later sections of this report.

The Great Lakes Critical Programs Act of 1990 amended § 118(c)(7) of the Clean Water Act to extend the ARCS Program for 1 year (to December 31, 1993) and specified completion dates for certain interim activities. The ARCS Program has completed all of its activities within the time frame mandated by the Act.

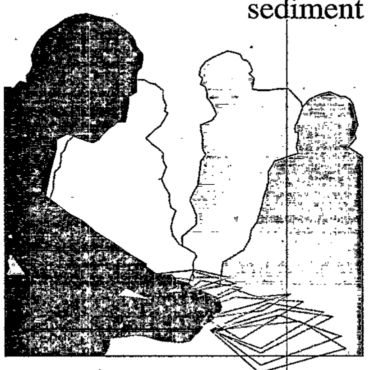
The ARCS Program conducted all of its activities in the most cost-effective manner. Existing and accepted testing protocols were used rather than undertaking the costly task of developing new testing procedures. The ARCS Program worked closely with other local, State, Federal, and international programs to avoid costly duplications in effort. In addition, because the Sheboygan Harbor and Ashtabula River AOCs



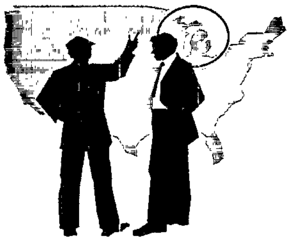
Completion dates for critical ARCS Program elements.

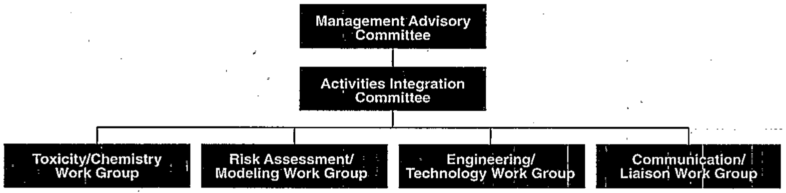
were already undergoing intensive study under the Superfund program, the ARCS Program chose to focus its resources on activities such as sediment sampling and laboratory treatment technology investigations for those priority AOCs that did not already have the benefit of these activities under Superfund.

The results of the ARCS Program effort will be of continuing use in addressing sediment contamination problems both within the Great Lakes region and nationally. In particular, information gained and tools developed for assessing sediment contamination and for making remediation decisions will help to streamline efforts to address contaminated sediment concerns in all of the identified Great Lakes AOCs. In addition, the information gained through the ARCS Program activities will be incorporated into the *EPA's Contaminated Sediment Management Strategy* currently being developed by USEPA Headquarters in cooperation with the Regional USEPA offices and other agencies and organizations.



Organizational Structure of the ARCS Program





To meet the objectives and to address each of the issues discussed earlier in this report, the ARCS Program developed the overall organizational structure illustrated. The responsibilities of each identified committee and work group were as follows:

Management Advisory Committee

The Management Advisory Committee was responsible for providing advice on ARCS Program activities. Its membership included representatives from many of the organizations identified in the participant list provided at the end of this report.

Activities Integration Committee

The Activities Integration Committee was responsible for providing oversight of the ARCS Program, including the activities of the work groups discussed below. This committee coordinated quality assurance and quality control (QA/QC) and data management activities of the ARCS Program to ensure consistency among work group activities.

Toxicity/Chemistry Work Group

The Toxicity/Chemistry Work Group was responsible for evaluating and testing sediment assessment methods. This work group assessed the current nature and extent of contaminated sediment problems by studying chemical, physical, and biological characteristics of contaminated sediments and their biotic communities, and demonstrated cost-effective sediment assessment techniques at the priority AOCs.

Risk Assessment/Modeling Work Group

The Risk Assessment/Modeling Work Group was responsible for assessing the current and future risks presented by contaminated sediments to all biota (aquatic, terrestrial, and human) under the "no action" and various remedial alternatives at the priority AOCs, and developing techniques for assessing the environmental impacts resulting from the implementation of remedial alternatives. Modeling was performed to predict possible impacts from various sediment remedial alternatives. A system for prioritizing sites with contaminated sediments was also developed to provide a comparative framework for assessing multiple sites that are potentially in need of remediation.

Engineering/Technology Work Group

The Engineering/Technology Work Group was responsible for evaluating and testing available remediation technologies for contaminated sediments, selecting promising technologies for further testing, performing field demonstrations of promising technologies at the priority AOCs, and estimating the costs of and contaminant losses during remediation.

Communication/Liaison Work Group

The Communication/Liaison Work Group was responsible for facilitating the flow of information from the technical work groups and the overall ARCS Program to the interested public and providing feedback from the public to the ARCS Program on needs, expectations, and perceived problems.

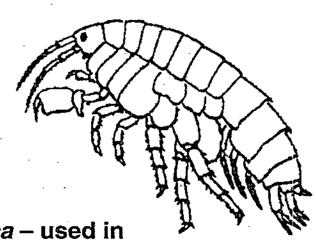
Findings and Recommendations of the ARCS Program

The findings of the ARCS Program that were summarized earlier in this report are discussed in more detail in this section.

Integrated Sediment Assessment Approach

Development and demonstration of state-of-the-art assessment tools were key objectives of the ARCS Program. To this end, the ARCS Program evaluated various assessment tools to develop the most cost-effective, yet scientifically sound, means of assessing sediments. Based on this evaluation, the ARCS Program concluded that an integrated sediment assessment approach provides the means to adequately evaluate whether sediments are contaminated, what contaminants are present, and the severity of the contamination problem. The integrated sediment assessment approach helps to ensure that a sufficient body of information is collected to define "hot spot" areas and, in turn, to support making environmentally sound decisions.

Use of an integrated sediment assessment approach is absolutely essential to accurately define the magnitude and extent of sediment contamination at a site

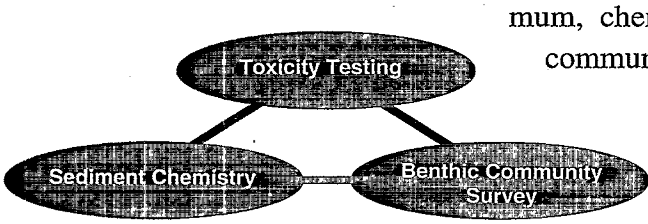


Hyalella azteca – used in sediment toxicity tests.

The ARCS Program developed detailed guidance for sampling sediments; selecting and conducting chemical, toxicity, and biological analyses; and interpreting sediment data. This information is described in the *ARCS Assessment Guidance Document.* In developing sediment assessment guidance and conducting sediment assessment activities during the ARCS Program, rigorous QA/QC protocols were followed to ensure that the information gathered was scientifically credible and therefore will be useful in making contaminated sediment cleanup decisions in the future.

Findings

The first step in any evaluation of contaminated sediments is to identify the magnitude and extent of the problem. Through the Toxicity/Chemistry Work Group, the ARCS Program demonstrated that a comprehensive, integrated assessment approach that includes, at a minimum, chemical analyses, toxicity testing, and benthic community surveys may be needed to accurately characterize the magnitude and extent of the sediment contamination problem. Each of these assessment components provides information about different aspects of the contamination problem: chemical analyses provide information about which toxic substances are present; toxicity test results provide information about how the toxic substances might affect organisms; and benthic community surveys of organisms living in the sediments provide an indication of the long-term impacts that may result from toxic contamination. Integration of these results thus provides a clear picture of the amounts and effects of contaminants present in the sediments.



Conducting sediment assessments typically requires that many samples be taken in order to adequately characterize the magnitude and extent of sediment contamination at a given site. However, chemical and biological analyses of these samples can be expensive. Therefore, the ARCS

Program found that where historical information is limited, a preliminary survey using screening-level analyses should be conducted prior to undertaking the more rigorous and costly integrated sediment assessment. The screening-level analyses include a set of relatively inexpensive, semiquantitative tests that can be conducted quickly in the field. The results of screening-level analyses can then be used to focus later sampling efforts during the integrated sediment assessment by defining the area (potentially smaller than that evaluated in the screening-level analysis) that warrants more detailed testing.

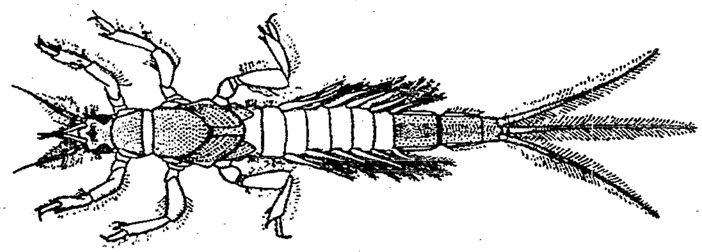
Screening-Level Analyses

Technique	Parameters
Immunoassays	PCBs Pesticides PAHs
Fluorescence Spectroscopy	PAHs
X-ray Fluorescence Spectroscopy	Metals
Microtox®	Acute Toxicity

PCBs	polychlorinated biphenyls
PAHs	polycyclic aromatic hydrocarbons

Recommended Tests and Tools for Performing an Integrated Sediment Assessment

One key objective of the ARCS Program was the development of guidance on the performance and application of integrated sediment assessments that may be used to assist in RAP development at AOCs. To this end, the ARCS Program evaluated a variety of assessment tools (e.g., sediment sampling, chemical and biological testing approaches, data interpretation techniques) in an effort to develop the most cost-effective, yet scientifically sound, means of assessing sediments. The most promising techniques were then applied at demonstration areas in the Buffalo River, Grand Calumet River, and Saginaw Bay priority AOCs. Again, in an effort to



***Hexagenia bilineata* – used in sediment toxicity tests.**

minimize duplication of effort between activities in the ARCS Program and the Superfund program, sediment assessment activities were not undertaken at the Ashtabula River and Sheboygan Harbor AOCs.

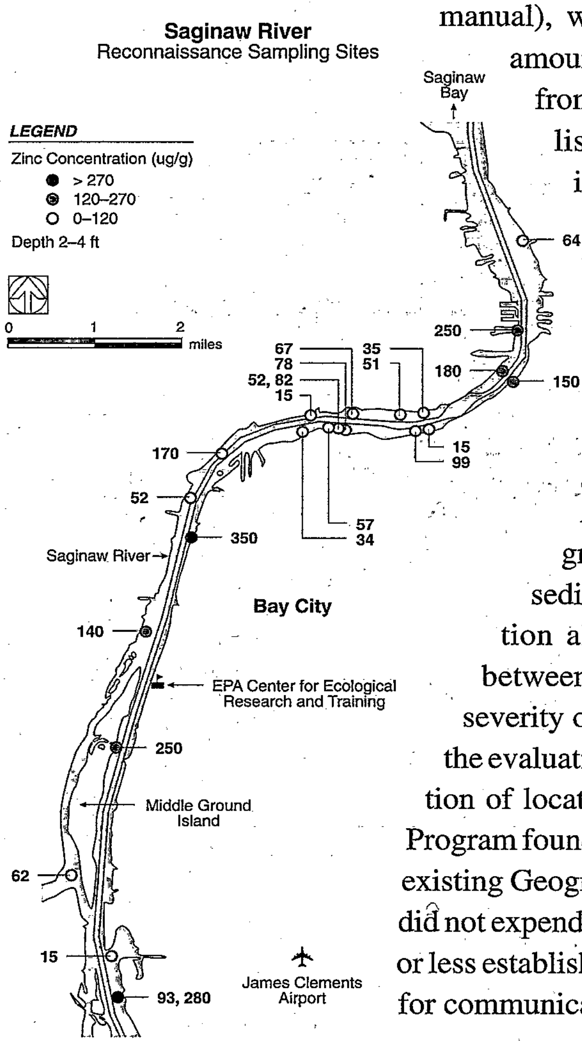
Chemical and Biological Analyses

Because protocols for conducting sediment chemistry analyses are fairly well established, the ARCS Program determined that it would be most appropriate to recommend the use of existing chemical test methods. The ARCS Program did, however, evaluate a myriad of possible biological toxicity tests (approximately 17 organisms, 97 endpoints, and more than 7,600 data points), and based on these evaluations developed guidance for the selection of a tailored battery of toxicity tests from a list of recommended tests to be used at AOCs (see table below). Here again, the ARCS Program relied on verifying the capabilities of known toxicity tests, rather than undertaking the costly proposition of developing new tests.

RECOMMENDED SEDIMENT TOXICITY TESTS

Organism	Duration	Endpoints
Hyalella azteca Amphipod	10–28 day	Survival, length, sexual maturation
Ceriodaphnia dubia Cladoceran	7 day	Survival, reproduction
Chironomus riparius Midge	14 day	Survival, length
Chironomus tentans Midge	10 day	Survival, growth
Daphnia magna Cladoceran	7 day	Survival, reproduction
Pimephales promelas Fathead minnow	7 day	Larval growth
***Pontoporeia hoyi (Diporeia* sp.)** Amphipod	5 day	Preference/avoidance
Hexagenia bilineata Mayfly	10 day	Survival, molting frequency

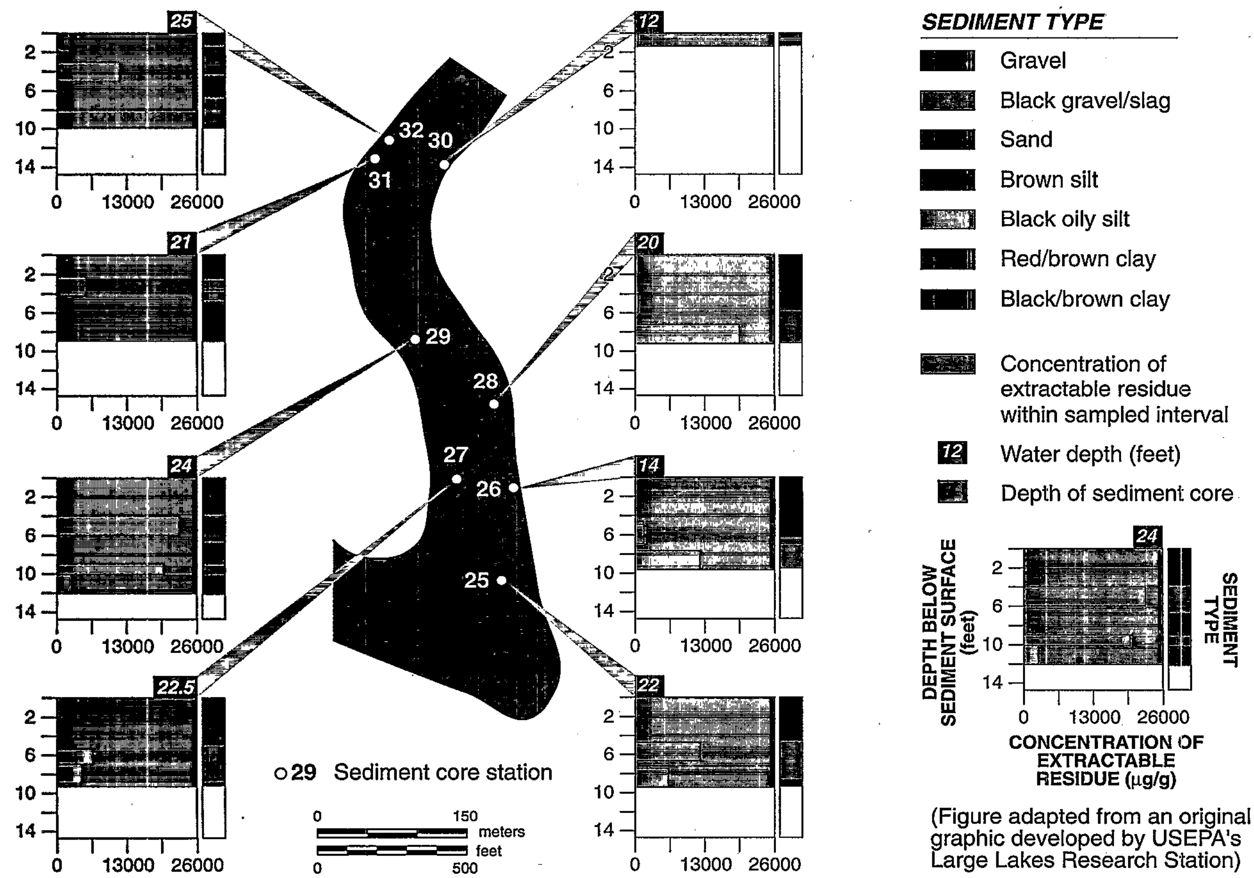
Although the *Chironomus tentans* bioassay did not perform well during the ARCS Program, it is included in the recommended toxicity test list because of subsequent improvements in the test methods made by USEPA's Environmental Research Laboratory in Duluth, Minnesota, during the development of USEPA's manual–*Procedures for Assessing the Toxicity and Bioaccumulation of Sediment Associated Contaminants with Freshwater Invertebrates*. Also, the 10-day duration tests using *Chironomus tentans* and *Hyalella azteca* are included as "minimum biological testing requirements" (as defined in the above-referenced manual), with the longer durations being used to enhance the amount of information on chronic toxicity that can be gained from the tests. Note that all of the tests that appear on the list have varying strengths and weaknesses and are intended to be used in a battery, or suite, of tests when applied at a specific site. The *ARCS Assessment Guidance Document* contains detailed procedures for selecting the proper tests for use at a specific site.



Visual Presentation of Data

Another sediment assessment tool that the ARCS Program found to be very valuable was the mapping of sediment chemical and biological data. A visual presentation allows for easier interpretation of the relationships between chemical and biological data and the extent and severity of the sediment contamination problem, and can aid in the evaluation of potential remedial alternatives and the identification of locations where they might be implemented. The ARCS Program found that the sediment data could be readily depicted using existing Geographic Information System (GIS) technology, and thus did not expend unnecessary time and money to invent or evaluate new or less established mapping approaches. Maps are also a valuable tool for communicating this information to the public.

The ARCS Program also input the sediment assessment data from the three AOCs into the existing Ocean Data Evaluation System (ODES) database. Because ODES is a national database, these data from the Great Lakes are now available for further evaluation by others around the country.

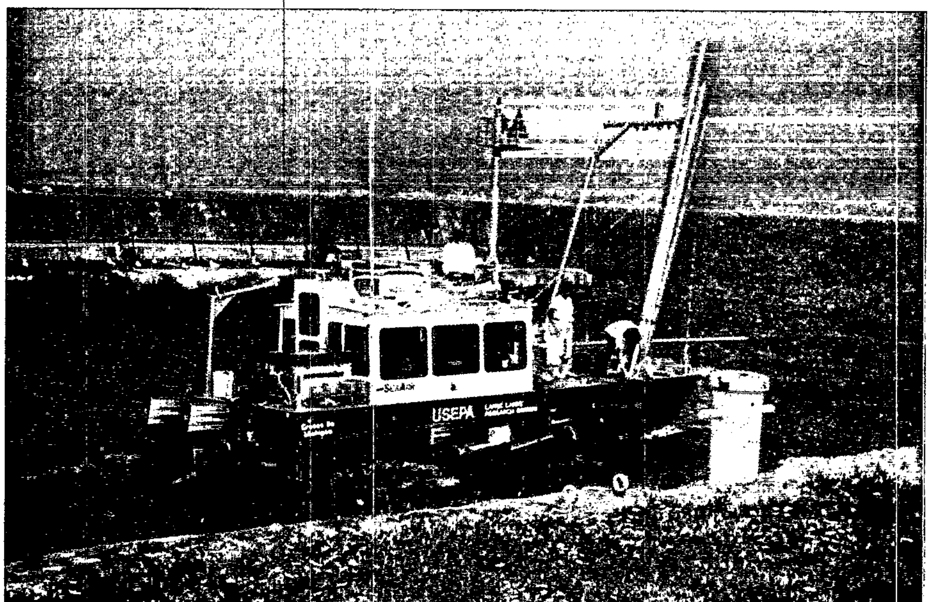


(Figure adapted from an original graphic developed by USEPA's Large Lakes Research Station)

1990 Buffalo River sediment survey.

Research Vessel (R/V) Mudpuppy

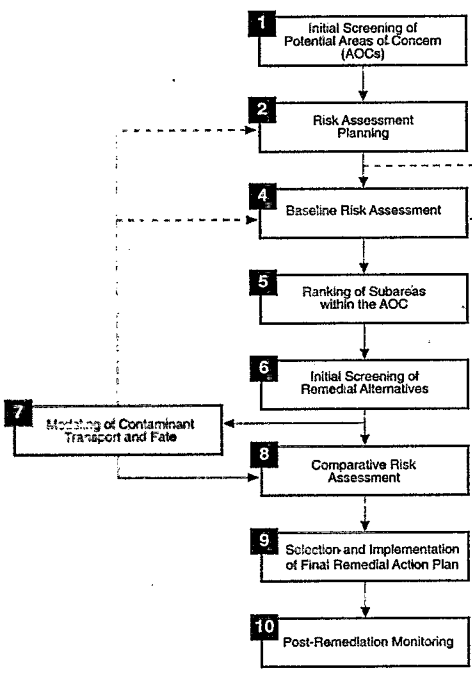
Another tool that was key to the success of the ARCS Program sampling efforts and that demonstrates USEPA's long-term commitment to the evaluation and remediation of contaminated sediments in the Great Lakes Basin was the R/V *Mudpuppy*. This sampling boat was specifically designed and developed for the ARCS Program to support sediment sampling activities, and is equipped with a vibro-corer capable of collecting sediment core samples up to 6 meters in length. It is currently in use and will continue to be available for sediment sampling efforts in the Great Lakes AOCs and other areas in the Great Lakes system.



Risk Assessment and Modeling Activities

Risk assessment and modeling activities are valuable techniques for evaluating the potential impacts associated with contaminated sediments

The ARCS Program found that risk assessment activities, including a baseline risk assessment and predictive assessments using the mass balance modeling approach, are valuable techniques for determining the magnitude of the risks associated with current sediment contamination and for predicting reductions or increases in risk over time following the implementation of different remedial actions. This information in turn provides a scientific basis for making remedial response decisions.



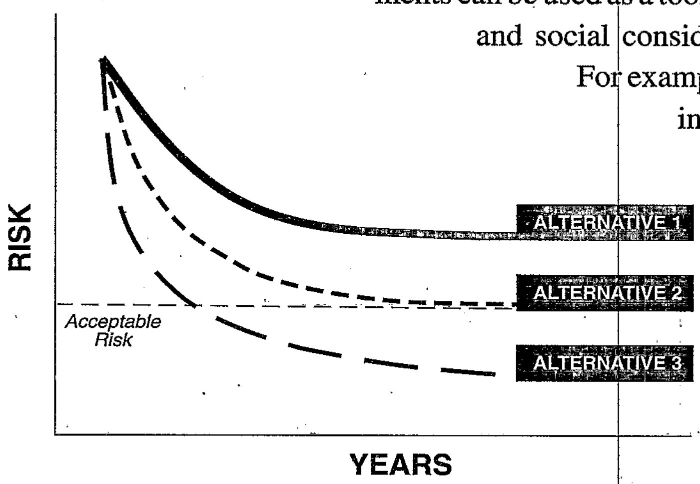
Based on the results of field sampling, a number of potential remediation scenarios were examined for the Buffalo River and Saginaw Bay AOCs using the mass balance modeling approach. Scenarios identified included dredging the entire river, dredging site-specific "hot spots," and capping "hot spots" in place. These scenarios must be compared to each other and to the "no action" alternative to determine which actions prove most beneficial overall in each system. Guidance on performing risk assessment and modeling activities is provided in the *ARCS Risk Assessment and Modeling Overview Document.*

Overview of the comprehensive risk management process.

Findings

Once the extent of sediment contamination at a site is determined, one must consider the risks that might be posed both by current contaminant levels and by predicted future contaminant levels. This requires the performance of both baseline and predictive risk assessments. Baseline risk assessments are used to determine current risk conditions. The results of these assessments can be used to make decisions regarding the need for remediation now, and to determine in the future whether risks have increased or decreased over time with changes in the levels of sediment contamination. Predictive assessments are used to estimate and compare the risks that may be associated with different remedial alternatives (including the "no action" alternative). These predictions can be made by manipulating the information entered into the models used in the mass balance approach.

The information generated by the baseline and predictive risk assessments can be used as a tool in conjunction with other economic, policy, and social considerations in making remediation decisions. For example, if it is predicted that PCB concentrations in fish will be reduced if contaminated sediments are allowed to recover naturally, the "no action" remedial alternative may be appropriate. However, if it is predicted that it will take 25 years or more for PCB concentrations in fish to be reduced under the "no action" alternative, active remediation may be appropriate.



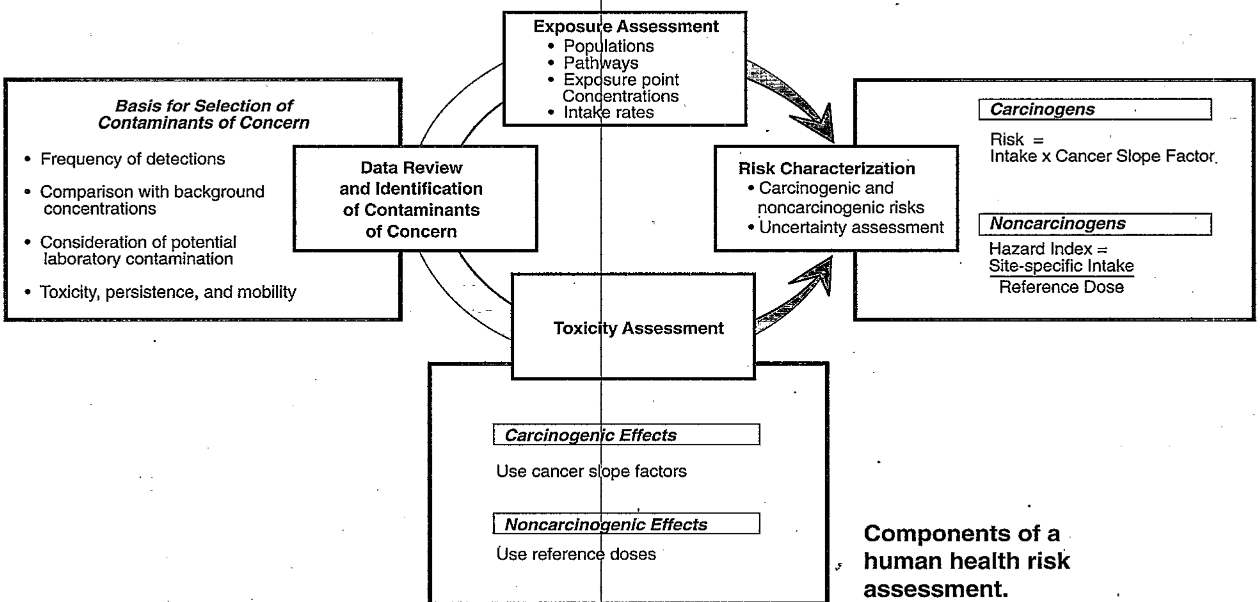
Comparisons can also be made between the predicted decreases in risk and the costs of conducting various remedial actions. This information can then be used as a basis for making remediation decisions. For example, if it is predicted that a very costly remedial alternative would result in only a small decrease in risk, that remedial alternative might be eliminated from consideration. The tradeoffs between risk reduction and cost need to be weighed in making remediation decisions at any contaminated site.

To conserve resources and prevent duplications in effort, the ARCS Program relied on existing Superfund guidance (USEPA's Risk Assessment Guidance of 1986) and other generally recognized risk assessment procedures in conducting risk assessment activities. The ARCS Program assessed risks to both human health and the environment. For the human health risk assessment activities, both cancer risks and non-cancer hazards potentially resulting from direct and indirect exposure to sediment contaminants were considered.

Baseline Risk Assessments

Receptors that should be evaluated in a baseline risk assessment (e.g., humans and/or ecological organisms, including aquatic, avian, and mammalian species) may vary depending on site-specific exposure conditions. The baseline risk assessment includes

evaluations of exposure pathways (e.g., dermal absorption, ingestion) from sediments to the receptors and the magnitude and frequency of exposure via all applicable pathways. The ARCS Program conducted baseline human health risk assessments at all five priority AOCs using available site-specific information. These assessments revealed that the primary pathway of risk to humans under present conditions at these AOCs is through the consumption of fish (this is likely the case for wildlife as well; other pathways may be more important at other locations). Human health risk levels associated with fish consumption were then derived based on an estimate of the magnitude and frequency of exposure by considering a range of consumption scenarios including typical, subsistence, and reasonable maximum consumption rates.



Components of a human health risk assessment.

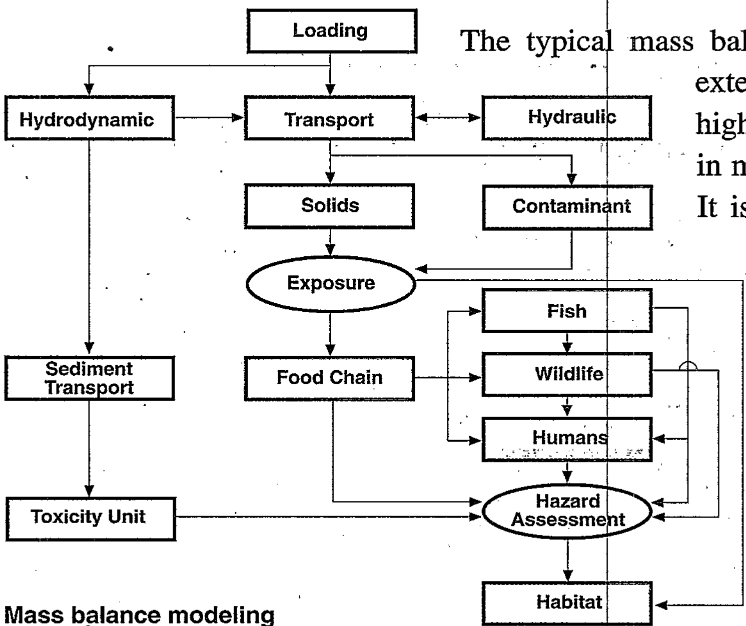
Predictive Risk Assessments: The Mass Balance Modeling Approach

Examples of remedial scenarios examined

- **Selective sediment removal**
- **Capping of hot spots**
- **Source control**
- **Dredging of an entire river**

Like the baseline risk assessment, predictive risk assessments can include an evaluation of human and/or ecological receptors depending on the specific exposure conditions at a given site. In general, predictive assessments are conducted by comparing exposure estimates with the changing levels of sediment contamination over time that would result from natural processes (e.g., sediment transport or the natural covering of contaminated sediments with clean sediments) or from implementation of different remedial actions. The purpose of the predictive assessments conducted by the ARCS Program was to help target scarce sediment cleanup dollars on areas where the greatest risk reduction would be cost-effective. The ARCS Program conducted predictive assessments, using the mass balance modeling approach, for the Buffalo River and Saginaw Bay AOCs. These assessments included an examination of risks to humans under different remediation scenarios.

The mass balance modeling approach involves quantification of the relationship between sources of contaminants to a natural system and the resulting concentrations in water, sediments, and biota. This linkage is accomplished by mathematically representing all important transport and fate processes in the system of interest. Existing models and methods were used in applying the mass balance modeling approach to the Buffalo River and Saginaw Bay AOCs. Specific modeling components considered by the ARCS Program included hydrodynamics to predict river flows; sediment transport to predict the interactions between transport, deposition, and resuspension processes under various meteorological and hydrological conditions; contaminant exposure to predict the effects of water and sediment transport and other processes on the concentrations of contaminants; and food chain modeling to estimate the effects of varying exposure concentrations on contaminant concentrations in the biota.



Mass balance modeling framework used in the ARCS Program.

The typical mass balance modeling approach requires an extensive database to generate results with a high enough degree of certainty to be of use in making remedial management decisions. It is recognized that use of the models to evaluate remedial actions at other AOCs may be limited by the availability of adequate funding to provide such a database. To make best use of its resources, the ARCS Program made an effort to define the minimum amount of data needed to generate information with an adequate degree of certainty for use in making management decisions. The ARCS Program found that although a significant amount of information is needed, it is possible to generate results of adequate quality and scientific certainty to assist in making important remedial management decisions. In any given application, acceptable levels of uncertainty, and thus the amount of data required, will need to be evaluated. The ARCS Program found that it was necessary to have highly skilled and experienced modelers running the mass balance models to reduce the amount of uncertainty to the point where meaningful information can be generated. This need for experienced modelers will continue into the foreseeable future, until models are developed that can be more readily used by less experienced individuals.

Remediation Technology Evaluation

The ARCS Program evaluated, and demonstrated in the laboratory and the field, the effectiveness, feasibility, and cost of numerous remediation treatment technologies. Several of those technologies were found to be technically feasible although they varied in their effectiveness depending on the contaminants present, and all of those evaluated cost more than traditional confined disposal. Sediment washing technologies were found to be promising in that they were feasible and could be conducted at the lowest cost.

Several treatment technologies are effective in removing contaminants from sediments

Guidance on making remedial decisions based on the results of these ARCS Program activities is provided in the *ARCS Remediation Guidance Document*. This guidance includes cost estimates for implementation of treatment technologies. These estimates include the costs associated with dredging, any pretreatment required by the technology, the cost of application of the technology itself, and the costs associated with final disposal of the residuals that will always remain after treatment.

Findings

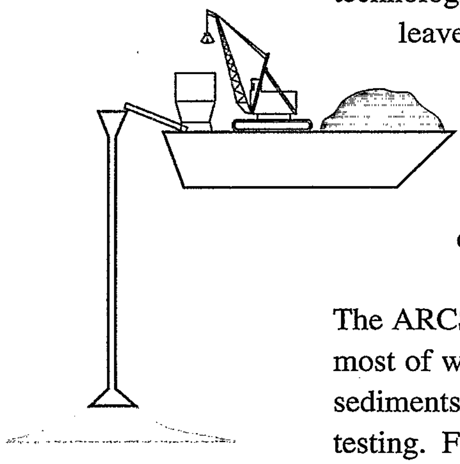
Once preliminary estimates are made of the magnitude and extent of sediment contamination and the associated risks to human health and the environment, a determination must be made whether remediation will be required. If so, a remedial alternative must be selected (e.g., active remediation, such as dredging contaminated sediments and treating them, or in-place remediation, such as capping or armoring of sediments).

Of the treatment technologies evaluated and demonstrated by the ARCS Program, no single technology was effective for all contaminants. Typically, technologies are designed to deal with either the organic contaminants (such as PCBs) or heavy-metal contaminants. Some of the technologies considered (e.g., particle separation and solidification) may effectively treat both types of contaminants, but their application is limited to sediments with specific characteristics that are not present at all sites. Complications due to the presence of certain contaminants may occur in the application of some technologies, and volatile contaminants may be lost unintentionally during the application of some thermal treatment processes. In addition, the treatment technologies were effective on only some types of sediment. These limitations suggest that a multiple-step treatment process may be necessary in some cases.

With the knowledge of dredging and sediment disposal activities already well advanced by previous research efforts, the ARCS Program focused its efforts on the evaluation and demonstration of treatment technologies for the remediation of contaminated sediments. Technologies that extract contaminants from sediments were identified as having high potential for successful remediation because of the nature of contamination in sediments. Specifically, the volume of sediments present at contaminated sites tends to be quite high, while the concentrations of contaminants in the sediments tend to be relatively low in comparison to those in contaminated soils at hazardous waste cleanup sites. Substantial cost savings can be achieved by applying extractive technologies first, thus reducing the volume of material requiring further treatment by more expensive destructive methods.

The ARCS Program focused on the evaluation of remediation technologies that traditionally had not been applied to contaminated sediment problems. This program management decision was not meant to preclude the continued use of traditional sediment remedial alternatives such as confined disposal facilities (CDFs); rather, it was made to help expand the knowledge base on sediment remedial alternatives so that in the future all options can be evaluated on a more equal basis. In this light, the treatment cost estimates that were developed during the pilot-scale demonstrations under the ARCS Program, and that are summarized in this report, can be compared to the cost of typical CDF disposal of around $20–$30 per cubic yard of sediment.

There are two broad categories of contaminated sediment treatment technologies: those that work on the sediments *in situ* and those that process sediment after dredging. Technologies for the treatment of contaminated sediments *in situ* were found to be less developed than the technologies that can be applied to dredged material. Any decision to leave sediments in place is highly dependent on an evaluation of the relative risks posed by the sediments left untreated on the bottom, the risks of performing a treatment operation on *in situ* sediments, and the risks associated with the removal and subsequent disposal or treatment of the contaminated dredged material.



The ARCS Program researched more than 250 treatment technologies, most of which had not been previously demonstrated on contaminated sediments. Nine of these technologies were selected for bench-scale testing. Four of the nine technologies were then selected for pilot-scale demonstrations. The ARCS Program conserved resources by testing only readily available technologies. To identify and evaluate new, untested approaches would require more time and funds than available. In addition, recognizing that decision-makers addressing the cleanup of contaminated sediments in areas around the Great Lakes may not have significant resources, the ARCS Program also targeted the most cost-effective remediation technologies for evaluation.

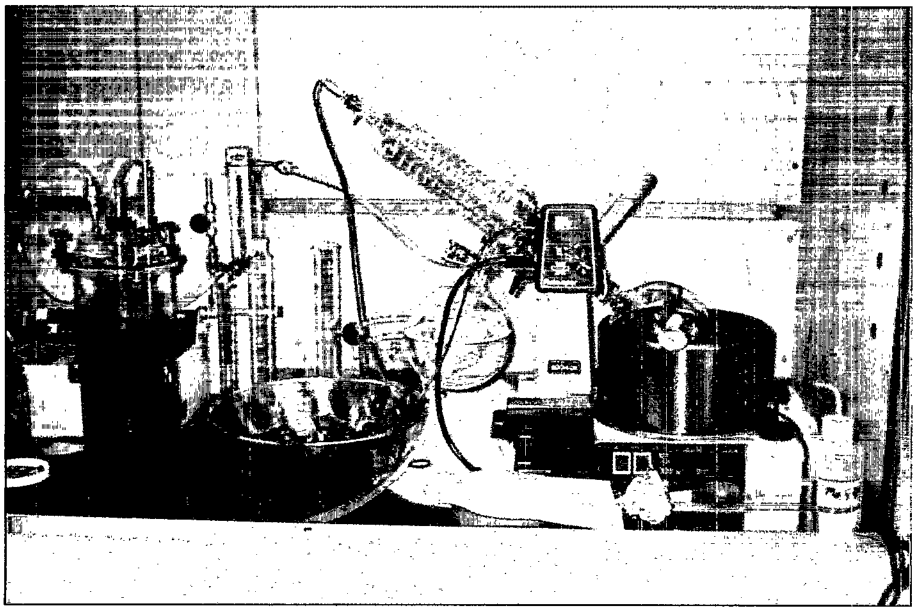
To identify the most promising technologies, the ARCS Program looked to other disciplines (e.g., the mining and metal processing industries) and also to other countries. The state of sediment treatment technology development, testing, and implementation was found to be advanced in the United States in comparison with efforts in Europe and Japan. The Canadian government began a similar sediment remediation demonstration project in 1990, and close cooperation between the ARCS Program and the Canadian project have helped optimize the use of both countries' resources. The nine technologies were selected for further evaluation based on their likelihood of success, and by considering ongoing evaluations by others, in order to avoid duplication of effort or overlapping investigations.

TREATMENT TECHNOLOGIES EVALUATED BY THE ARCS PROGRAM

- **Solidification/stabilization** – The addition of Portland cement, fly ash, or other binding agents to reduce the amount of contaminants that can leach from the sediments
- **Particle separation** – The application of mineral processing and mining techniques to separate clean sediment particles from contaminated sediment particles
- **Bioremediation** – The management and use of existing microorganisms to break down and destroy organic contaminants present in the sediment
- **Base catalyzed decomposition** – A process that uses simple chemical reagents to remove the chlorine atoms from contaminants such as PCBs
- **Basic Extractive Sludge Treatment (BEST®) process** – An extraction technology that uses the solvent triethylamine to remove and concentrate, but not destroy, organic contaminants from the sediments
- **Low temperature thermal desorption** – Several technologies that heat the sediments to temperatures less than those used in incinerators; the organic contaminants are vaporized from the sediments and then concentrated in an oil fraction, but they are not destroyed
- **Wet air oxidation** – The use of elevated temperature and pressure to break down and destroy organic contaminants such as polycyclic aromatic hydrocarbons (PAHs)
- **Thermal reduction (EcoLogic® process)** – The chemical reduction, or degradation, of organic contaminants in a heated reactor
- ***In situ* stabilization** – The use of clean materials to cap, or armor, sediment deposits in place at the bottom of a river or harbor.

Bench-Scale Testing

Many of the nine selected technologies had not been developed specifically for the treatment of contaminated sediments and had never been tested on sediments either in the laboratory or the field. Therefore, ARCS Program personnel decided it would be appropriate to first evaluate the technologies in the laboratory, in what are referred to as bench-scale tests, prior to evaluating their performance in field demonstrations. The nine technologies were tested in the laboratory on a few grams or kilograms of sediment collected from the priority AOCs. The selection of which technology to use on sediments from the different priority AOCs depended on matching the characteristics of each technology with the specific sediment type and contaminants present (e.g., a PCB treatment technology would be matched with sediments from a location having PCB contamination problems). The results of the bench-scale testing provided preliminary feasibility data and design data for the pilot-scale demonstrations.



Bench-scale evaluation of a solvent extraction process.

Pilot-Scale Demonstrations

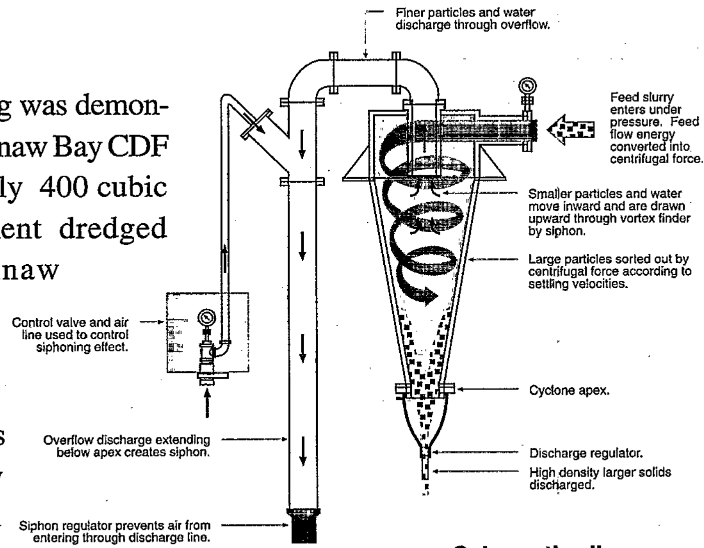
Pilot-scale demonstrations involved onsite field testing of a treatment technology on as much as several thousand cubic yards of sediment from the five priority AOCs. These demonstration projects are summarized below.

Buffalo River

Low temperature thermal desorption, which uses indirect heat to separate organic contaminants from contaminated sediments through volatilization, was demonstrated on 12 cubic yards of sediment from the Buffalo River AOC. This technology consists primarily of a twin-screw heating element, which the sediments pass over and around to be heated. Hot, molten salt flows through the interior of the twin screws and heats the sediments to temperatures up to 500°F. Organic contaminants are volatilized, or vaporized, from the sediments and then condensed and collected in a separate residual oil product that is much smaller in volume than the original contaminated sediments. This technology was selected for the Buffalo River AOC because it was previously shown to be successful in the removal of organic contaminants (e.g., PAHs) from sediments, which are of particular concern at this location. Following the treatment demonstration, sediment samples were analyzed for PCBs, PAHs, and heavy metals to determine how effectively and efficiently this process removes organic contaminants. The process removed more than 80 percent of the PAHs present in the Buffalo River sediments and revealed several material handling problems that will assist engineers in designing full-scale sediment treatment units. The estimated cost of applying this technology to sediments with the same physical characteristics and contaminant concentrations as Buffalo River sediments is between \$350 and \$535 per cubic yard of sediment (depending on the volume of material treated), not including the costs of dredging and storage of the material prior to treatment.

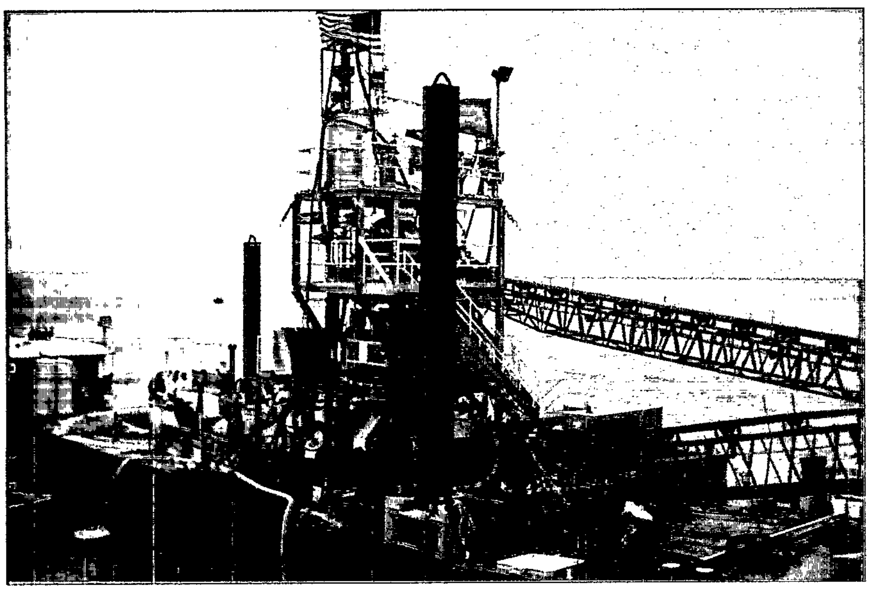
Saginaw River

Sediment washing was demonstrated at the Saginaw Bay CDF on approximately 400 cubic yards of sediment dredged from the Saginaw River. Sediment washing equipment such as hydrocyclones are used routinely in the mining and mineral processing industries to separate slurries into sets of different-sized particles.



Schematic diagram of a hydrocyclone.

The sediments were fed into the treatment process by conveyor. As sand and fine fractions were separated, they were collected in different areas of the CDF. Bench-scale studies suggested that because sediment contaminants have a tendency to associate with the fine-grained particles such as silts and clays, the particle size separation unit used in this demonstration could substantially reduce the volume of contaminated sediment. In this demonstration project, samples collected at more than 20 different points in the treatment process were analyzed to see if the particles were effectively separated by



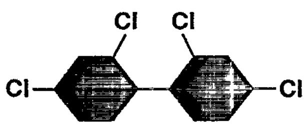
Pilot-scale sediment washing demonstration at Saginaw River.

size, and if the contaminants indeed remained with the silts and clays. The sediment washing process was very effective in separating clean sands from contaminated silts and clays, and produced a sand fraction, representing about 75 percent of the mass of the feed material, that could be considered for beneficial reuse (e.g., beach nourishment) instead of requiring confined disposal. The estimated cost of applying this technology to sediments with the same physical characteristics and contaminant concentrations as Saginaw River sediments is between $39 and $224 per cubic yard of sediment (depending on the volume of material treated).

Grand Calumet River

The BEST® process was demonstrated on 10 batches of 100 lbs of contaminated sediment taken from two locations on the Grand Calumet River. This demonstration was a cooperative effort between the ARCS Program and USEPA's Superfund Innovative Technology Evaluation Program. The BEST® process was selected for this demonstration project because of its ability to remove oil and other organic contaminants, which are of great concern in this AOC. The BEST® process uses the solvent triethylamine to separate organic contaminants such as PCBs from sediment. This technology takes advantage of the unique properties of triethylamine, which mixes with water only when it is chilled. When heated, the water and triethylamine are easily separated. During the process, chilled solvent is mixed with the sediments, and the sediment particles are then separated from the water, solvent, and organic liquid mixture. The liquid mixture is then heated to separate the water, reusable solvent, and an oily fraction that contains the organic contaminants in much higher concentrations, but in a much smaller volume compared to the original volume of sediment. Sediment samples and treated residues were collected. More than 98 percent of the total PAHs and total PCBs were removed from the Grand Calumet River sediments using the BEST® process. The estimated cost of applying this technology to sediments with the same physical characteristics and contaminant concentrations as Grand Calumet River sediments is between $138 and $357 per cubic yard of sediment (depending on the volume of material treated), not including the costs of dredging, storage of the material prior to treatment, and final disposal of process residuals.

Ashtabula River



2, 2', 4, 4'-
Tetrachlorobiphenyl
(PCB).

The same low temperature thermal desorption technology that was used in the Buffalo River demonstration was also used on approximately 15 cubic yards of sediment in the Ashtabula River demonstration. This technology was repeated at the Ashtabula River AOC to test its capabilities for treating contaminants such as PCBs and other chlorinated hydrocarbons that were not present in significant concentrations at the Buffalo River AOC. Sediments, treated solids, and condensed organic compounds present at the end of the process were sampled and analyzed for PCBs, PAHs, semivolatile compounds, chlorinated volatile compounds, and heavy metals to determine how effectively and efficiently the process removed these contaminants from the sediments. The process removed 86 percent of the PCBs, up to 99 percent of the semivolatile compounds, and more than 92 percent of the chlorinated volatile compounds. Mercury was the only heavy metal removed by the process. The cost of applying this technology is estimated to be similar to the costs developed during the Buffalo River demonstration–between $350 and $535 per cubic yard of sediment–not including the costs of dredging and storage of the material prior to treatment.

Sheboygan River

Bioremediation was demonstrated on contaminated sediments from this priority AOC. This demonstration was performed in conjunction with Superfund activities being conducted by Tecumseh Products, a potentially responsible party, at this site. Tecumseh had removed 2,700 cubic yards of PCB-contaminated sediment from the river and had stored it in a confined treatment facility (CTF). USEPA developed a plan with Tecumseh to manipulate the contents of the CTF to enhance naturally occurring biodegradation. Manipulation consisted of adding nutrients to sediments already containing indigenous populations of microorganisms (bacteria and fungi), and cycling the CTF between aerobic and anaerobic conditions (PCBs do not completely degrade either aerobically or anaerobically). The demonstration confirmed that the PCBs present in the Sheboygan River sediments had already undergone a great deal of anaerobic dechlorination. However, questions remain about developing a properly engineered system to deliver adequate amounts of oxygen to the sediments in order to break down the remaining partially dechlorinated PCB molecules. Cost estimates have not been developed for this type of bioremediation application, and the remaining questions concerning the engineering design of a full-scale system must be answered before realistic costs can be determined.

Outreach Activities

An essential component of the ARCS Program was the active involvement of the public in all decision-making and demonstration activities. The ARCS Program concluded that broad public involvement and education is critical to the success of any sediment assessment and remedy selection study. Such interaction is critical in order to develop a common understanding of the problem and the environmental and economic impacts of remedial alternatives, to minimize fears and misconceptions about the severity of contamination and associated risks, and to ensure that public concerns are adequately addressed.

Broad public involvement and education is critical in any sediment assessment and remedy selection study in order to develop a common understanding of the problem and the environmental and economic impacts of alternative remedial actions

Findings

The ARCS Program maintained a high degree of public outreach and participation throughout the study. Numerous environmental and public interest groups assisted the ARCS Program in defining the nature of the sediment contamination problem and in defining appropriate assessment and remediation study activities on which to focus. This participation included representation from the local RAP committees responsible for developing RAPs for the five priority AOCs considered by the ARCS Program.

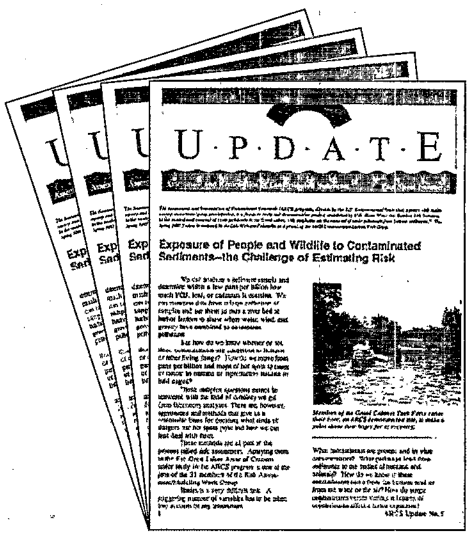
The ARCS Program found that for this effort to be successful, information must be disseminated to scientists, decision-makers, and the public involved in the assessment and remediation of contaminated sediments. To this end, technical workshops were, and will continue to be, held on sediment assessment techniques, risk assessment, and remedial option selection. These workshops in turn help to continue building expertise for addressing sediment contamination problems throughout the Great Lakes Basin.

The ARCS Program did not limit itself by seeking ideas from only local interests, but looked worldwide to gather the best and most up-to-date sediment assessment and treatment technology information. ARCS Program representatives met with Japanese representatives to discuss treatment technologies, reviewed international literature on sediment assessment and sediment remediation techniques, and discussed these subjects with scientists from the Netherlands, Belgium, Germany, Scotland, and England. ARCS Program representatives also communicated with representatives of demonstration programs managed under the Canadian Great Lakes Cleanup Fund.

The ARCS Program Communication/Liaison Work Group included members from public interest groups, Federal and State agencies, and individual citizens that live in the vicinity of AOCs. The members of this work group were responsible for disseminating ARCS Program and related sediment information to the interested public (a mailing list of more than 1,000 people was developed). In addition, citizen representatives were included as members on each of the technical work groups.

Information about ARCS Program activities has been widely distributed to the public in the form of *ARCS Update* fact sheets, news releases, a slide show, public meetings, and public open houses held at the five priority

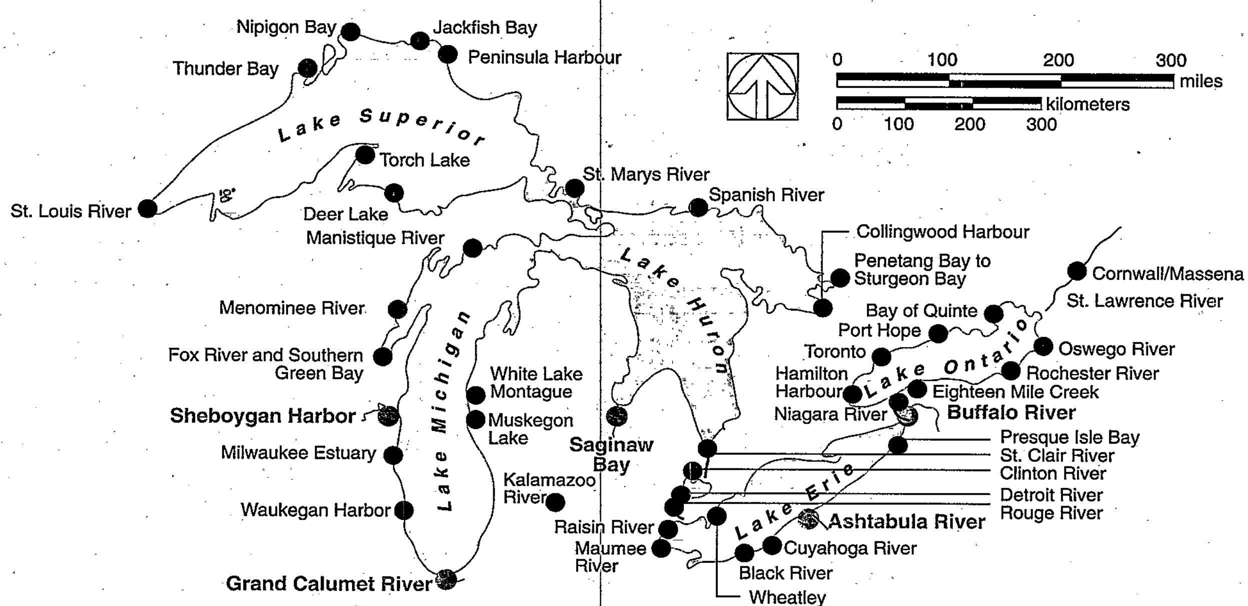
AOCs. The ARCS Program has made all written documentation continuously accessible by setting up repositories for ARCS Program material and other information on contaminated sediments in local libraries in the vicinity of the five priority AOCs. Workshops were also held in 1992 and 1993 to communicate ARCS Program efforts to state RAP coordinators. In addition, ARCS Program personnel have given numerous oral presentations discussing the program's accomplishments at conferences and other gatherings. Through all of these activities, the ARCS Program continually solicited and received public input.



Conclusions/Challenges

The ARCS Program has demonstrated state-of-the-art methods for the assessment of contaminated sediments (especially in the area of toxicity testing) and has broken new ground in the application of the mass balance modeling approach. The ARCS Program has made significant contributions to the knowledge base on contaminated sediment remediation by selecting promising treatment technologies, taking them out into the field, and demonstrating their effectiveness on site. The strong partnerships established among ARCS Program participants have played a key role in achieving program goals.

The major findings of the ARCS Program–the need to perform thorough, integrated sediment assessments, the importance of mass balance modeling in the evaluation of remediation scenarios, the identification and demonstration of several feasible sediment treatment technologies, and



Great Lakes Areas of Concern.

the recognition and success of public involvement and active participation in sediment assessment and remediation projects–are but a beginning in the continuing process of solving this complicated problem. One of the main objectives of the ARCS Program was to provide guidance to effectively address the contaminated sediment problem at Great Lakes AOCs. It is expected that much of the information and tools generated by the program will be used at AOCs over the next several years. Increasing the knowledge base through the transfer of this technology at the State and local levels and throughout USEPA is the next logical step.

Over the next year, the ARCS Program will accomplish this technology transfer objective through various avenues. Three guidance and overview documents were developed that provide guidance on: conducting sediment assessments, conducting risk assessments and mass balance modeling, and selecting appropriate sediment remediation technologies. Aside from the generation of documents, a number of technology transfer workshops are planned for the coming years. One such workshop addressing sediment assessment techniques was held in April 1993 at the University of Wisconsin-Madison. The main participants at these workshops are State agency representatives who are involved in implementing the RAPs being developed for the AOCs.

This *ARCS Program Final Summary Report* condenses the detailed results contained in the more than 40 individual project reports produced during the ARCS Program. At the time of the writing of this summary report, most of these project reports are in final stages of editing and publication. A list of report titles is provided at the end of this report to allow the reader to seek out those specific reports that cover their area of interest. In addition, library repositories that contain copies of all of these reports have been set up at several locations in the vicinity of each priority AOC. A list of those repository locations is provided at the end of this report.

ARCS Program personnel will dedicate the next several years to assisting programs throughout the Great Lakes Basin, including States, USEPA Regions, and RAP teams, as they address their contaminated sediment problems. The R/V *Mudpuppy* will remain a lasting symbol of the success of the ARCS Program as it is used basin-wide to collect the sediment samples necessary for further integrated assessment work. GLNPO will continue to support efforts in the development of economical, risk-reducing solutions to contaminated sediment problems.

The products of the ARCS Program will not, by themselves, eliminate the problems posed by contaminated sediments, nor do they propose one "cure all" treatment technology for their remediation. They do, however, provide guidance for the selection of sediment assessment and treatment technologies as well as recommendations for future full-scale applications. The results and products from the ARCS Program will have far-reaching implications for the remediation of contaminated sediments within the Great Lakes as well as on a nationwide basis.

The contaminated sediment problem in the Great Lakes Basin is large in scope and magnitude. It is responsible for both localized impacts by degrading habitat and causing toxicity to benthic organisms as well as long-range impacts by being a source of contaminants to the food chain. We are just beginning to understand how widespread these sediment contaminants are and what their impacts are on biota and wildlife. Given the potentially large cost of remediating all the contaminated sediment deposits in the Great Lakes, there is a need to find a way to better define the problem and determine its impacts, so that scarce resources can be strategically targeted at those contaminated sediments posing the greatest risk to the basin.

The field assessment, contaminant fate modeling, risk assessment, and remediation technology techniques demonstrated in the ARCS Program have improved our knowledge base and will enable us to make scientifically sound decisions. Although the cost and difficulty of solving the contaminated sediment problem in the Great Lakes will be significant, this body of work represents a key step toward ensuring the most judicious use of scarce financial resources.

Acknowledgments

As mentioned earlier, the success of the ARCS Program is a direct result of the multi-disciplinary approach taken in the management and structure of the program. All of the disciplines necessary to complete the ARCS Program were not present within the Federal government, or within USEPA. Many people from many different organizations made contributions that were vital to the development and execution of the ARCS Program.

The ARCS Program was managed by the Remedial Programs Staff of GLNPO, located in Chicago. Chris Grundler and Carol Finch were Directors of GLNPO during the ARCS Program. Both Paul Horvatin and Dave Cowgill served as the Chief of the Remedial Programs staff during the ARCS Program, while Mr. Cowgill and Marc Tuchman served as ARCS Program managers. The Toxicity/Chemistry Work Group was chaired by Philippe Ross of The Citadel and Rick Fox of GLNPO; the Risk Assessment/Modeling Work Group was chaired by Dr. Tuchman; the Engineering/Technology Work Group was chaired by Steve Yaksich of the Buffalo District, U.S. Army Corps of Engineers; and the Communications/Liaison Work Group was co-chaired by Glenda Daniel of the Lake Michigan Federation and a host of USEPA public affairs specialists, the most recent of whom was Phil Hoffman. The ARCS Quality Assurance Program was managed by Brian Schumacher of the USEPA Environmental Monitoring Systems Laboratory in Las Vegas, Nevada. GLNPO staff support to the ARCS Program was provided by Ralph Christensen, Diane Dennis-Flagler, Mark Elster, Cynthia Fuller, Darlene Funches, Steve Garbaciak, Rita Hartwig, Tony Kizlauskas, Katherine Schroer, Mary Beth Tuohy, and George Ziegenhorn.

Although GLNPO was responsible for the management of the ARCS Program, there were several individuals from outside USEPA without whose dedication and perseverance the ARCS Program could not have succeeded. Some of these individuals, along with the GLNPO ARCS Program staff, have already received recognition through the receipt of USEPA's Bronze Medal for Meritorious Service. However, it is worthwhile to once again identify those who helped make the program a success including: Daniel Averett, U.S. Army Engineer Waterways Experiment Station; G. Allen Burton, Wright State University; Eric Crecelius, Battelle Marine Sciences Laboratory; Chris Ingersoll, U.S. Fish and Wildlife Service; Jan Miller, U.S. Army Engineer Division, North Central; and William Richardson, USEPA Large Lakes Research Station.

The ARCS Program would also like to specifically acknowledge the key role played by USEPA's Office of Research and Development (ORD) for the wide-ranging support they provided. The ORD laboratories involved in this effort included: Environmental Research Laboratory-Duluth; Large Lakes Research Station-Grosse Ile; Environmental Research Laboratory-Athens; Environmental Monitoring Systems Laboratory-Las Vegas; and the Risk Reduction Engineering Laboratory. These laboratories played a key role in sediment assessment and sampling, mass balance modeling, QA/QC, and technology demonstration support.

Additional individuals that participated in the ARCS Program, either as work group members, contributing scientists and engineers, or other parties, are shown in the list that follows. The ARCS Program staff have tried to recall the names of everyone who was part of the program over the past 5 years, and hope that any omissions are few.

■ ■ ■

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ARCS Program Reports

The following are the working titles of the project reports to be published under the ARCS Program. Where a report has been published as of July 1994, an EPA publication number is given to facilitate acquiring the report. Limited copies of all ARCS reports will be available from the Great Lakes National Program Office, as supply lasts (please see the GLNPO address on the last page).

ARCS Assessment Guidance Document (EPA-905-B94-002)
ARCS Program Final Summary Report (EPA-905-S-94-001)
ARCS Remediation Guidance Document (EPA-905-B94-003)
ARCS Risk Assessment and Modeling Overview Document (EPA-905-R93-007)
Baseline Human Health Risk Assessment: Grand Calumet River, Indiana, Area of Concern
Baseline Human Health Risk Assessment: Buffalo River, New York, Area of Concern (EPA-905-R93-008)
Baseline Human Health Risk Assessment: Saginaw River, Michigan, Area of Concern (EPA-905-R92-008)
Baseline Human Health Risk Resulting from PCB Contamination at the Sheboygan River, Wisconsin, Area of Concern (EPA-905-R93-001)
Baseline Human Health Risk Assessment: Ashtabula River, Ohio, Area of Concern (EPA-905-R92-007)
Bench-Scale Evaluation of Bioremediation on Contaminated Sediments from the Ashtabula, Buffalo, Saginaw and Sheboygan Rivers
Bench-Scale Evaluation of RCC's Basic Extractive Sludge Treatment (B.E.S.T.) Process on Contaminated Sediments from the Buffalo, Grand Calumet and Saginaw Rivers (EPA-905-R94-010)
Bench-Scale Evaluation of Sediment Treatment Technologies Summary Report (EPA-905-R94-011)
Bench-Scale Evaluation of SoilTech's Anaerobic Thermal Process Technology on Contaminated Sediments from the Buffalo and Grand Calumet Rivers (EPA-905-R94-009)
Bench-Scale Evaluation of ReTeC's Thermal Desorption Technology on Contaminated Sediments from the Ashtabula River (EPA-905-R94-008)
Bench-Scale Evaluation of Zimpro's Wet Air Oxidation Process on Contaminated Sediments from the Grand Calumet River (EPA-905-R94-007)
Biological and Chemical Assessment of Contaminated Great Lakes Sediment (EPA-905-R93-006)
Biological Remediation of Contaminated Sediments, with Special Emphasis on the Great Lakes (EPA-600-9-91-001)

Buffalo River Mass Balance Modeling Study Results
Concept Plans for the Remediation of Contaminated Sediments in the Great Lakes
An Evaluation of Solidification/Stabilization Technology for Buffalo River Sediment[1]
Information Summary, Area of Concern: Saginaw River, Michigan[1]
Information Summary, Area of Concern: Grand Calumet River, Indiana[1]
Information Summary, Area of Concern: Ashtabula River, Ohio[1]
Information Summary, Area of Concern: Sheboygan River, Wisconsin[1]
Information Summary, Area of Concern: Buffalo River, New York[1]
Layman's Guide to Contaminated Sediment
Mineral Processing Pretreatment of Contaminated Great Lakes Sediments
Modeling Data Requirements and Mass Loading Estimates for the Buffalo River Mass Balance Study (EPA-905-R94-005)
A Multi-Assay/Multi-Test Site Evaluation of Sediment Toxicity
Numerical Ranking Methodologies for Contaminated Sediments
Pilot-Scale Demonstration of Solvent Extraction for the Treatment of Grand Calumet River Sediments (EPA-905-R94-003)
Pilot-Scale Demonstration of Bioremediation for the Treatment of Sheboygan River Sediments
Pilot-Scale Demonstration of Sediment Washing for the Treatment of Saginaw River Sediments
Pilot-Scale Demonstration of Thermal Desorption for the Treatment of Buffalo River Sediments (EPA-905-R93-005)
Pilot-Scale Demonstration of Thermal Desorption for the Treatment of Ashtabula River Sediments
Pollutant Loadings to the Buffalo River Area of Concern from Inactive Hazardous Waste Sites (EPA-905-R94-006)
Review and Synthesis of Bioassessment Methodologies for Freshwater Contaminated Sediments[1]
Review of Removal, Containment and Treatment Technologies for Remediation of Contaminated Sediment in the Great Lakes, 1994 Update
Review of Removal, Containment and Treatment Technologies for Remediation of Contaminated Sediment in the Great Lakes[1]
Saginaw River Mass Balance Modeling Study Results
Summary of Data Inputs to the Saginaw River Mass Balance Modeling Study
Tumors and Abnormalities in Fish from the Ashtabula and Buffalo Rivers
Wildlife Hazard Assessment: Saginaw River Area of Concern
Wildlife Hazard Assessment: Buffalo River Area of Concern

1 This report was published by the U.S. Army Corps of Engineers. Copies are available, while supplies last, from GLNPO.

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Ashtabula County District Library
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Ashtabula Ohio 44004
Phone: 216-997-9341

Buffalo River

Buffalo and Erie County Public Library
Attn: Science Department
Lafayette Square
Buffalo, New York 14203
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Buffalo, New York 14220
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Buffalo, New York 14222
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Gary Public Library
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East Chicago, Indiana 46312
Phone: 219-397-2453

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Gary, Indiana 46408
Phone: 219-980-6580

Saginaw River

Hoyt Library
Attn: Michigan Room
505 Janes Street
Saginaw, Michigan 48605
Phone: 517-755-0904

Bay City Branch Library
708 Center Avenue
Bay City, Michigan 48708
Phone: 517-893-9566

Saginaw Valley State University
Attn: Zahnow Library (reference)
2250 Pierce Road
University Center, Michigan 48710
Phone: 517-790-4240

Sheboygan River

Mead Public Library
710 Plaza 8
Sheboygan, Wisconsin 53081
Phone: 414-459-3432

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Phone: 312-353-2022

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Phone: 312-939-0838

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Windsor, Ontario N9A 6T3
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